ESA Discovery and Preparation – OSIP

Campaign on Remote Sensing of Plastic Marine Litter

Mapping Windrows as Proxies for Marine Litter Monitoring from Space

Executive Summary Report

Date 22/12/2021

Ref.: A1843-002_D9

ESA contract no. 4000130627/20/NL/GLC

Project name: **Mapping Windrows as Proxies for Marine Litter Monitoring from Space**

Document title: **Executive Summary Report**

Reference no.: **A1843-002_D6**

Issue date: **22/12/2021**

Issue and revision: **1.1**

ESA contract no.: **4000130627/20/NL/GLC**

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Acronyms

EO	Earth Observation
ESA	European Space Agency
FAI	Floating Algae Index
GNDVI	Green Normalised Difference Vegetation Index
LSA	Luxembourg Space Agency
MD	Marine Debris
NDVI	Normalised Difference Vegetation Index
NDWI	Normalised Difference Water Index
RAM	Random Access Memory
WASP	Windrows AS Proxies
WSI	WASP Spectral Index

Executive Summary

The WASP project, funded by the Discovery Element of the ESA's Basic Activities, follows on from the processor developed for the ESA project EO Tracking of Marine Litter in the Mediterranean Sea. The WASP Marine Litter processor is the current iteration of the EO Track processor that made use of multiple spectral indices constructed using the discrete wavelengths available to the Sentinel-2 MSI sensor alongside a deterministic decision tree classifier to identify floating marine plastic in Sentinel-2 images. The successes of the project were that plastic on the water's surface in large quantities was identified with this processor methodology, and that Sentinel-2 products delivered enough information at an acceptable resolution to allow for the construction of a viable processor. The limitations of the method were that it was constructed using a limited dataset and required manual interpretation of the results to discern the false positives from the true detections.

Any floating marine plastic which is likely to be present in areas around this larger debris patch have a high chance of being incorporated into it, as the hydrological effects which acted to form the large coalesced debris patch will act to move all floating material towards the patch. Indeed, convergence phenomena occurring at the sea surface will act as an accumulating factor for all passive floaters within the area of influence of the phenomena itself. If litter is present, it will be aggregated along other surfactants and floating materials.

Windrows are another known hydrological phenomenon which are generated by persistent winds over large areas of open water. Their large size makes them visible to the Sentinel-2 Multi-Spectral Imager (MSI) and any floating material in the vicinity of a windrow will tend to aggregate to it, making them a viable proxy for marine debris.

Figure 1: Examples of ocean windrows. (Left) Off the coast of Honduras, in the Caribbean Sea. (Right) Off the south coast of Spain, in the Mediterranean Sea.

Ship-based studies focused on marine litter windrows are rare, especially those addressing their attracting effect on marine life. The shortage of field information is explained by the lack of knowledge on how to find litter windrows, and the fact that usually they are not properly investigated when encountered. Here we argue how understanding marine litter pollution requires targeted windrow research. Aerial surveys already allow to advance in the knowledge of the frequency of occurrence and location of macro-litter windrows on a large scale. Macro-litter windrows are the greatest hope for systematically monitoring ocean litter pollution on a global scale from space-borne sensors. Given that litter windrows can only be formed from particularly high ambient litter loads, the detections of litter windrows represent severe-pollution flags, useful for tagging highly-polluted zones and periods, or for assessing the effectiveness of waste management plans on the basis of suitable detection statistics.

Based on these findings, the goal of the project was to develop an automatic processor which can identify windrow phenomena in Copernicus Sentinel-2 products, and to use this processor to construct a database of filament detections across the Mediterranean Sea from all available Sentinel-2 products over the region.

Several additional developments to the processor were required to enable accurate identification of windrows. This included an improved methodology for cloud masking which combined the efforts of four existing cloud masks, an improved land mask to reduce the possibility of a windrow being erroneously identified over a non-water region, and a machine-learning filament identification algorithm to identify the distinctive shapes which are taken by windrows. This was all combined with an improved resampling methodology making use of the Super-Resolution algorithm to increase the resolution of all bands, up to 10m, ahead of applying a reworked plastic identification index to the identified filament to determine the likelihood of it containing plastic.

Copernicus Sentinel-2 products were used as input for the processor, sourced from the Luxembourg Space Agency (LSA) Data Centre. All water-containing tiles of the Mediterranean Sea were requested for the WASP processor to run on, which totalled 287,475 products across 404 tiles over the imaging lifetime of Sentinel-2 A and B up until the present. These were provided across 7 batches due to the memory taken up by such a large number of products.

The system that the WASP processor was installed on is the Adwaisëo computing cluster, allocating a total of 30 cores and 640GB of RAM to run the processor. Processing the entirety of the input dataset took roughly 1.5 months of discontinuous processing time. As each batch had to be processed separately, downtime was associated with processing the results of each batch and setting up the next batch in between runs. Following the full processing run, 104,286 output products were generated from the full input dataset. Within these output products, a total of 708,355 filaments were identified by the processor and classed as Good or Bad detections, prior to validation as True or False detections.

Validation of the outputs was performed manually by operators who binned each of the snippets according to whether it was a True filament detection, according to a set of identified characteristics across the processor user guide, or a False detection, where the feature highlighted as a filament was not determined to be a windrow or floating MD. Once validation of these output products was completed, statistics on the processor results showed an accuracy of 89.14% in classifying windrow filaments. A density plot of filament locations revealed an increased concentration of filaments on the Western side of the Mediterranean, as well as around key coastal regions such as the Po River mouth and the southern coast of Spain. This is possibly related to the increase in rainfall on the western side of the Mediterranean, as more rain would cause more litter to potentially be washed into the Mediterranean Sea, however this theory will require further investigation to be verified.

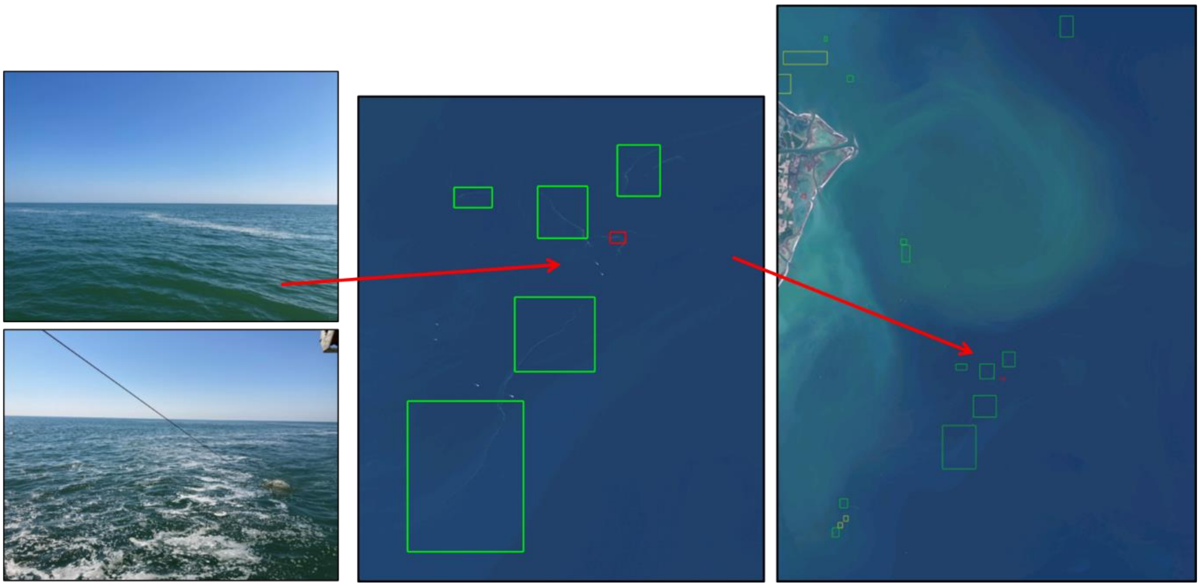

Figure 2: Example of various windrows found during the processing campaign, complemented by its corresponding Sentinel-2 observation, and the detections done by WASP.

In addition to the full processing run over the Mediterranean Sea, six selected test sites were chosen for the verification of the processor, as these were known Sentinel-2 tiles where MD filaments had been previously identified. These included the mouth of the Po River and the cities of Calabria and Rome in Italy, the Greek islands of Crete and Lesvos and finally, the city of Granada and Punta del Cerron in Spain. The processor being able to identify the plastic pixels on the campaign targets confirms that the index is suitable for identifying floating MD in sentinel-2 images.

The results of the processor seem to be the first to show the correlation of remote sensing observations of marine debris and land observations including information on population and rainfall trends. This shows the immense potential of the WASP processor in regional and potentially global marine debris monitoring using EO. Refinement and additional developments could be further explored. A paper in a high-impact journal is being ready for publication in 2022, which will put in value the great potential and capabilities of these approaches to inform and report of marine debris, as well as complementary data sources for other fields, including Biodiversity and VHR Physical Oceanography.

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